The Influence of Atmosphere – Ocean Interaction on MJO Development and Propagation

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LONG-TERM GOALS

The long-term goal of this project is to understand the role of the atmosphere-ocean interaction processes in the initiation, maintenance and propagation of Madden Julian Oscillation (MJO). Better grasp of the atmosphere/ocean feedbacks in the Tropics will allow formulating more accurate parameterizations of the air-sea interface in the forecasting models. It will contribute to improved predictability of the MJO and other coupled phenomena on various special and temporal scales.

OBJECTIVE

The objective of this research is to examine how atmospheric fluxes associated with convection influence the structure of salinity and temperature in the oceanic mixed layer in the Indian Ocean. The variability of SST and formation of salinity lenses is emphasized. The feedback of the sea surface variability on the formation of convective cells associated with the MJO will be assessed.

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APPROACH

The three ways coupled atmosphere-ocean-wave model (two-way interactive between COAMPS®[1] and NCOM; one way interactive with SWAN) is used to examine air-sea interaction in the Indian Ocean during the active and inactive phase of MJO. The model is used for process studies that aim to evaluate atmosphere-ocean feedbacks and their influence on MJO development, and for forecasting of air sea interaction in the Indian Ocean basin and its influence on MJO. The impact of various physical processes and their parameterizations on simulated on predictability of MJO is examined.

The integral part of this project is participation in the field experiment. We will provide forecasting support during the field phase and we will use the experiment data to constraint/evaluate modeling results. The field phase of this project will be associated with DYNAMO, which is the US contribution to the interactional experiment CINDY 2011.

WORK COMPLETED

In the past year, we primarily worked on:

1. Further analysis of hindcasts of MJO for April 2009 and winter 2009/2010
2. Analysis of air-sea interaction and the impact of the diurnal cycle of SST in observations and coupled COAMPS 5 day forecasts
3. Tested the fully coupled air-sea-wave forecasting system for the DYNAMO field phase

RESULTS

Analysis of MJO hindcasts

We examined the air-sea interaction and the response of the ocean to MJO forcing in hindcast experiments in which the atmospheric model consisted of series of 12 hour forecasts while the ocean model was running for about a month with no data assimilation. The results indicate that the coupled system is capable of reproducing the essential features of atmospheric and ocean circulation patterns related to MJO such as deepening of the ocean mixed layer, cooling of the ocean surface and development of ocean currents during the MJO active phase (Fig. 1) and high SST diurnal cycle preceding the active phase (Fig. 2)

Interestingly, sensitivity tests with different horizontal resolution forcing (Fig.3) showed that the mixed layer depth structure on the equator appears to be very sensitive to the atmospheric forcing, indicating that large wind stress on the equator is necessary for development of the observed mixed layer. Such a strong wind forcing was reproduced only when with the high resolution (9 km) atmospheric grid was used on the equator.

[1] COAMPS® is a registered trademark of the Naval Research Laboratory.

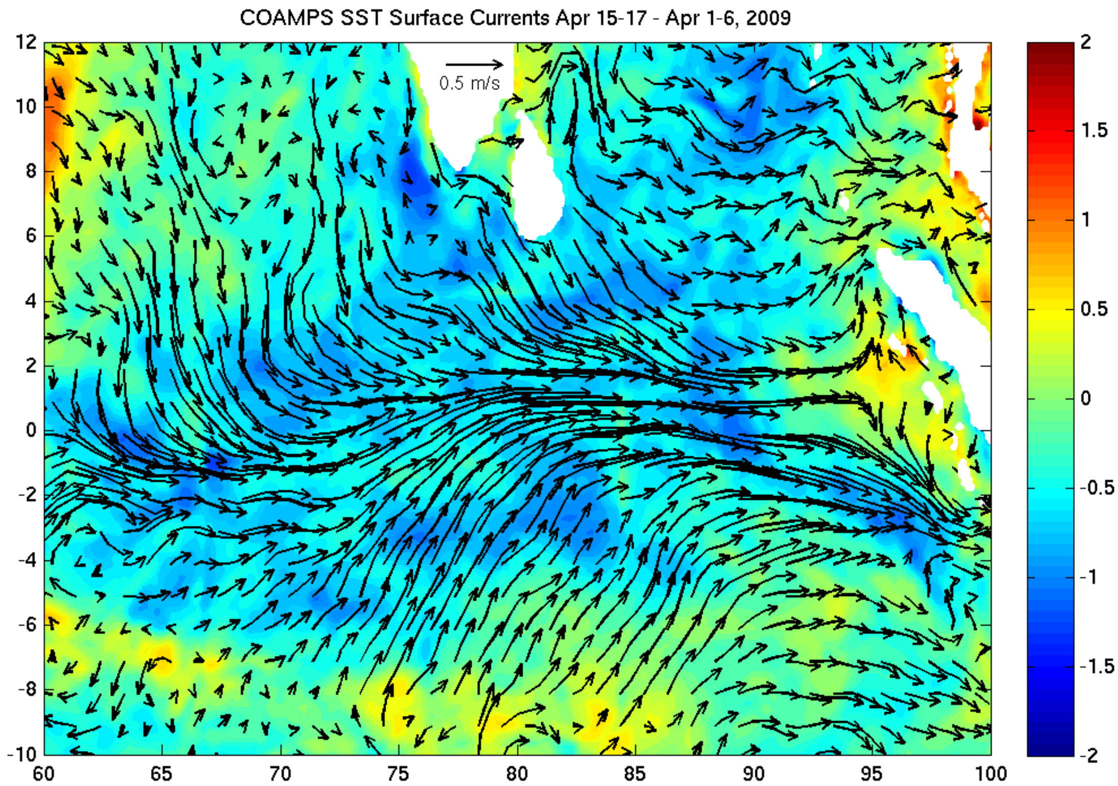

Fig1: Ocean response to the westerly wind event during April 2009: The development of the strong westerly jet (arrows) and large SST reduction (colors).

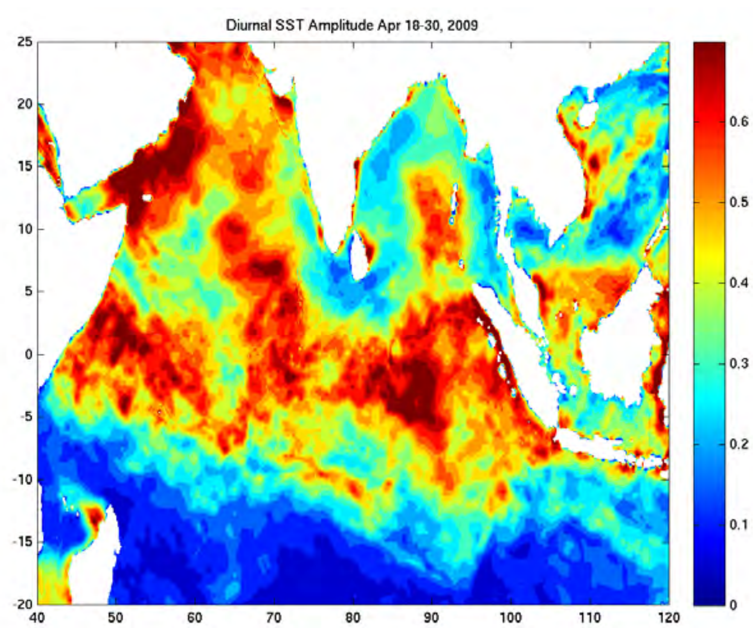

Figure 2. The amplitude of the diurnal SST change during the suppressed state of the MJO (April 18-30)

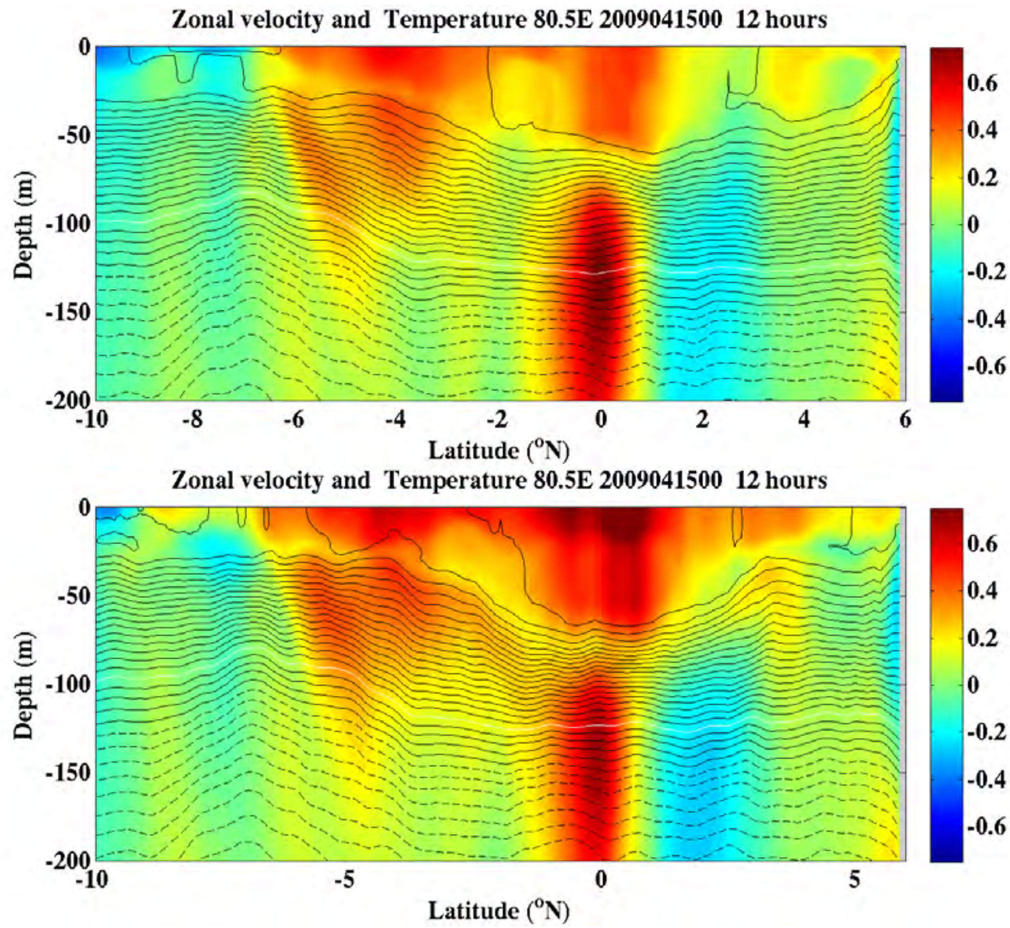

Figure 3. The comparison of the ocean mixed layer structure following the westerly burst at 0N 80E for weaker wind stress from the low resolution atmospheric mode (upper panel) and stronger wind stress from the high atmospheric resolution model (lower panel) The stronger surface current (shading) and warmer and deeper mixed layer (the contours show ocean temperature) are evident.

The influence of the diurnal SST cycle on development of convection in the coupled COAMPS forecasts.

Two five-days COAMPS forecasts were examined to determine the influence of SST variability on convection. Our results indicate that when the diurnal variability is taken into account the total precipitation as well as variability of the precipitation increases over the areas of large SST variability (Fig. 4). At the same time the noon precipitation maxima over the mountains in the Maritime Continent are reduced. Since diurnal cycle of precipitation over land is one of the reasons of MJO “blocking” by Maritime continent, this sensitivity to the ocean SST variability may impact the modeled MJO propagation.

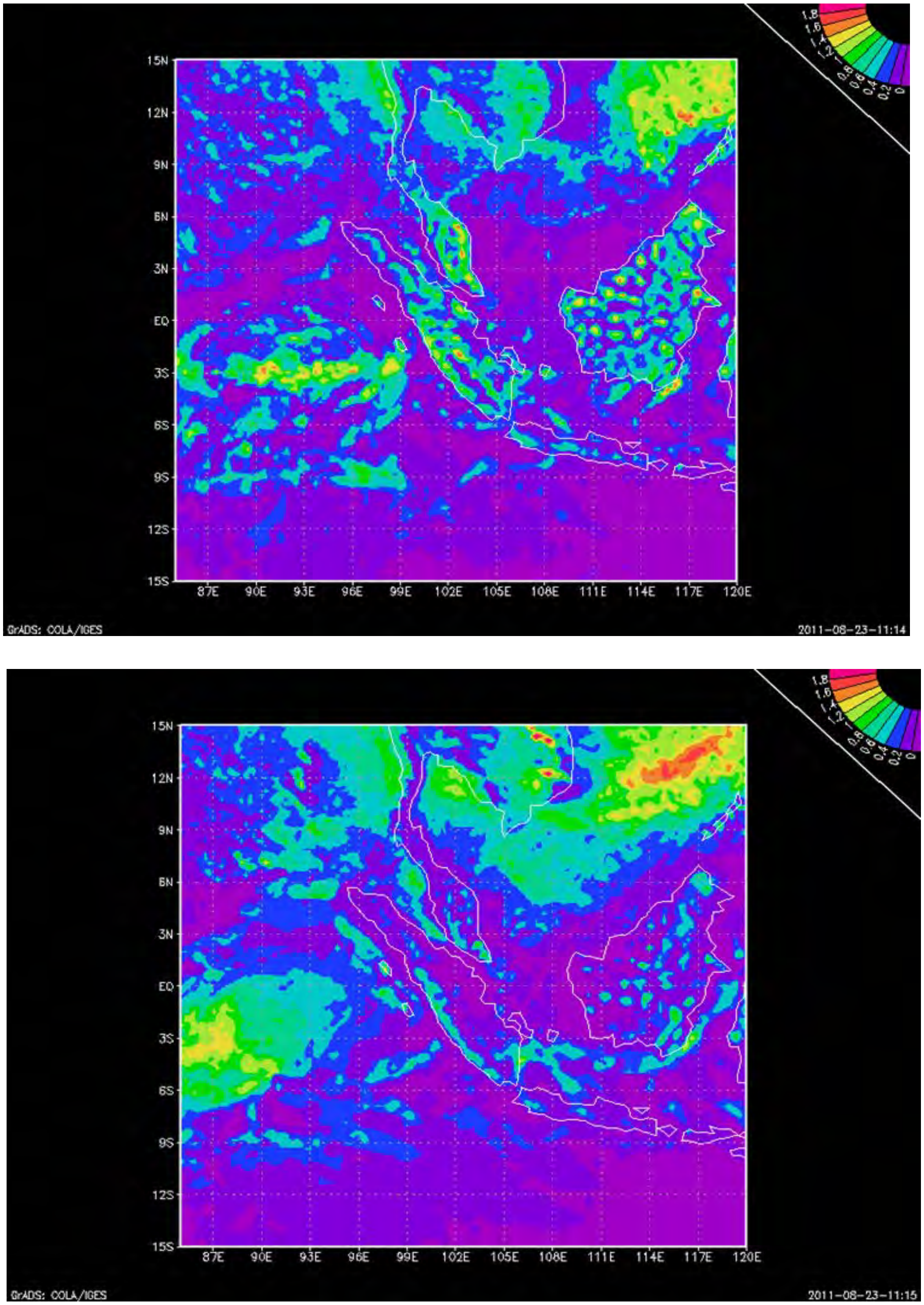

Figure 4: The influence of the air-sea coupling and the diurnal variability of SST on diurnal variability of the modeled precipitation. The upper figure shows the pattern of variability in the 5 day COAMPS forecast forced by constant SST while the lower figure shows the precipitation variability in the coupled experiment

Preparation of the real-time coupled COAMPS® forecast support for DYNAMO

The coupled COAMPS system was tested and fine-tuned for the use in the real time forecast support for the field phase. Over 70 atmosphere and ocean model products were developed with the inputs from DYNAMO PIs to best assist in instrument placements and flight planning. Fig. 5 shows the COAMPS forecast used in placement of the DYNAMO mooring. The simulation helped to identify the region of the largest shear of the ocean current which was the preferred location for the mooring

We participated in several DYNAMO "dry runs" and COAMPS model products were routinely uploaded into the DYNAMO catalog since beginning of September. Fig. 6 shows the equatorial OLR obtained from the coupled COAMPS for the August 17_September 18 period. The westward propagating Rossby wave features and easterly propagating dry MJO phase are evident. The model results are also compared with the forecasts from CFS, NICOM, and UH_HCM models. We plan to evaluate the model results against available DYNAMO observations during the field campaign

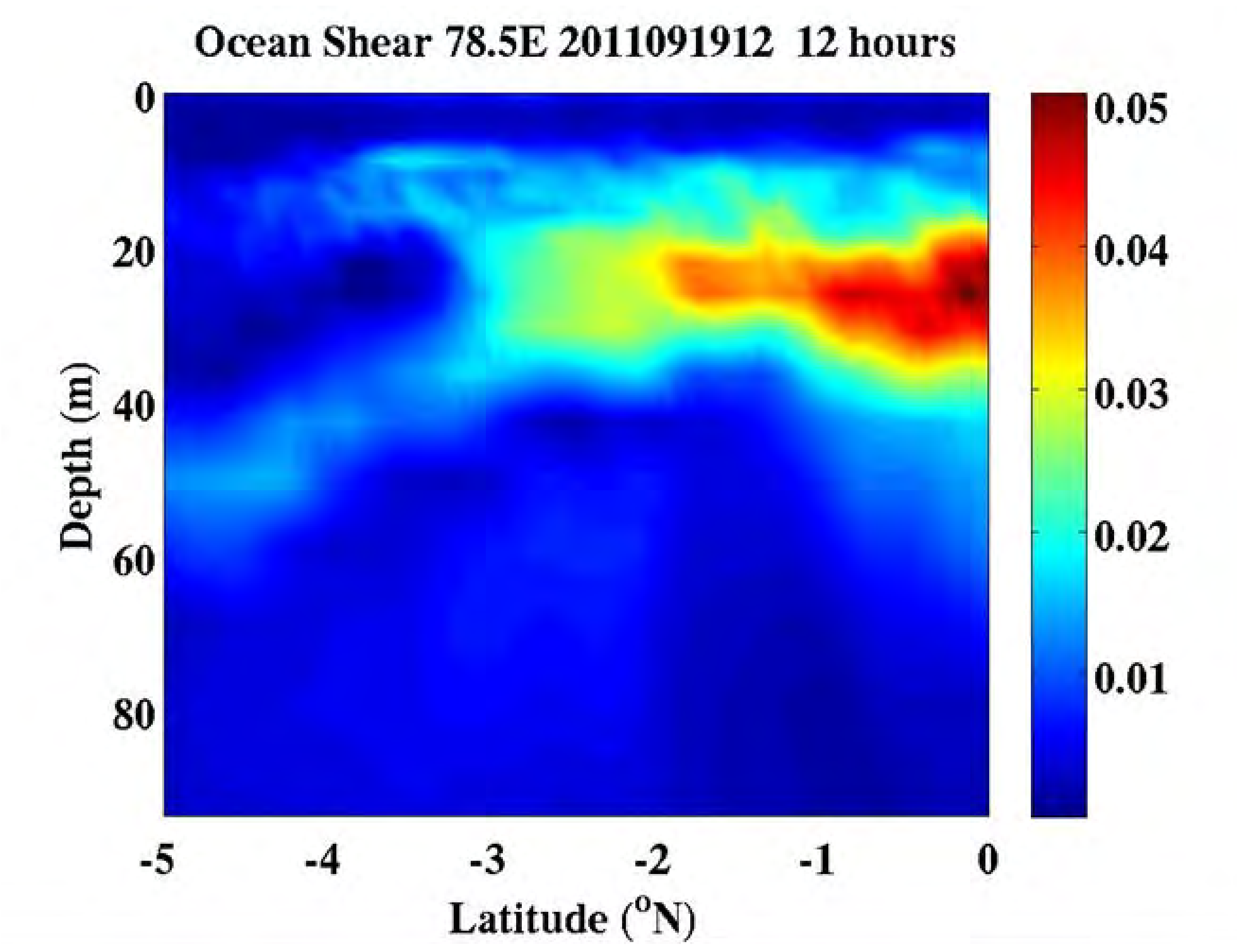

Figure 5: The 12 hour forecast of the ocean current shear used in the placement of the DYNAMO mooring.

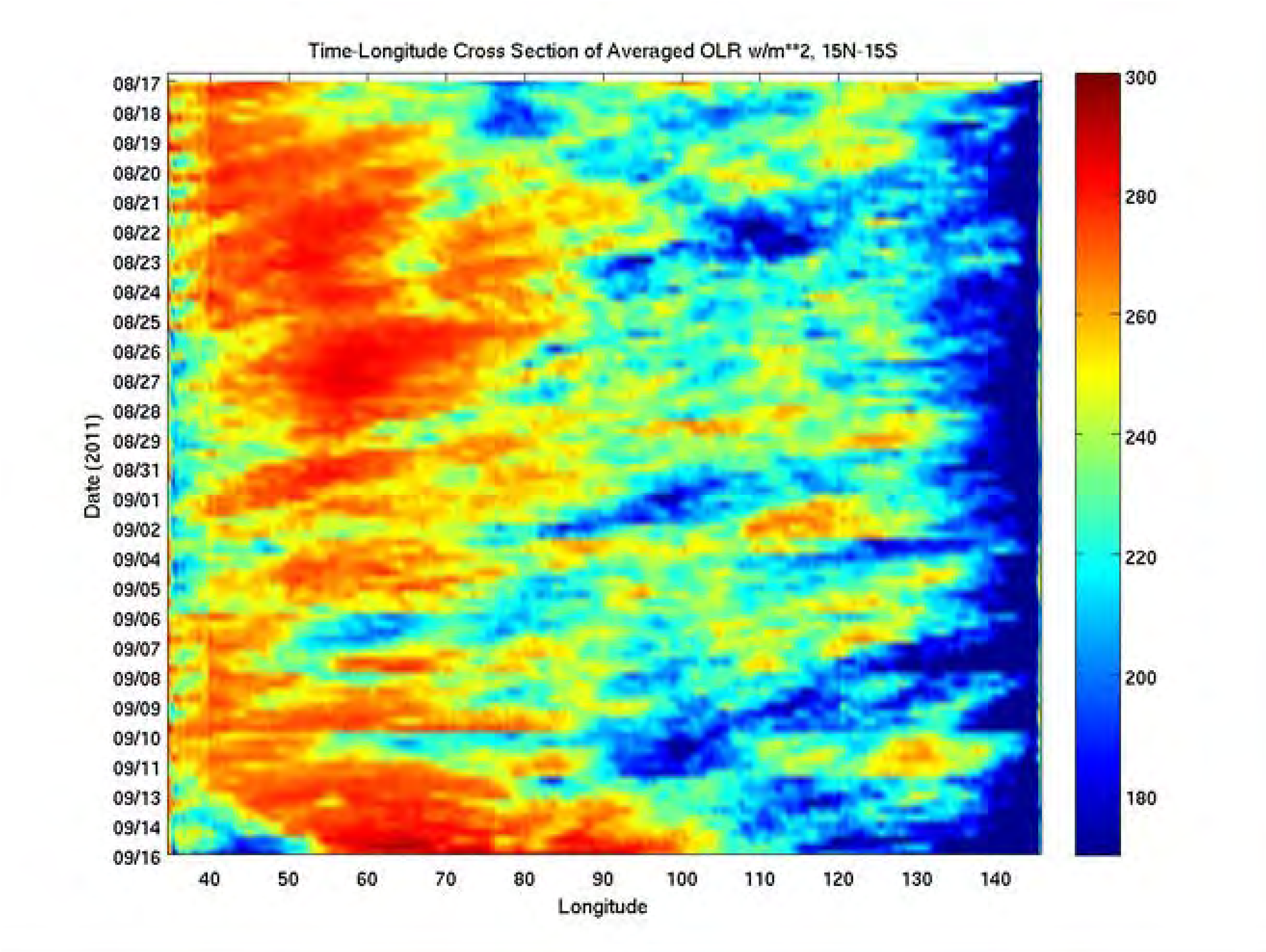

Figure 6: The Equatorial OLR from coupled COAMPS

IMPACT/APPLICATIONS

The project will contribute to the better understanding of feedbacks between convection and atmospheric and oceanic mixed layer. The knowledge gained in this project will allow us to formulate and test more accurate parameterizations, the variance/co variance of coupling, and to improve the forecasting capability of COAMPS® and possibly NOGAPS.

TRANSITIONS

The improvements to coupled COAMPS® that will result from this work and can be transitioned to the 6.2 COAMPS project.

RELATED PROJECTS

This project is a part of the ONR Air-Sea interaction DRI and we collaborate with other PIs involved in this initiative as well as with the wide, international group of researchers involved in CINDY

experiment. Some issues related to impact of the diurnal SST variability on convection are also addressed under 6.1 Tyranny of Scales base projects. We collaborate with dr. Reid on MJO-related convection (NASA project: A scale analysis of the relationships between biomass burning and the Maritime Continent's radiation and precipitation environment). The some MJO development problems will be considered in ONR-DRI 6.1 6.1-SeasnGBL.

PUBLICATIONS

Papers

J. S. Reid, P. Xian, E. J. Hyer, M. K. Flatau, E. M. Ramirez, F. J. Turk, C. R. Sampson, C. Zhang, E. M. Fukada, and E. D. Maloney (2011) Multi-scale meteorological conceptual model of observed active fire hotspot activity and smoke optical depth in the Maritime Continent. Atmos. Chem. Phys. Discuss., 11, 21091-21170, 2011 (the paper is published in Atmos. Chem. Phys. Discussions and in review for Atmos. Chem. Phys. journal)

Conferences/meetings/seminars

Sue Chen, Maria Flatau , Tommy Jensen, Toshiaki Shinoda: Air-Sea Interaction Influence on MJO Forecasts. CINDY planning meeting, Yokohama, Nov 14-16, 2010

Maria Flatau, Sue Chen, Tommy Jensen, Toshiaki Shinoda and James Cummings: Diurnal SST cycle and initiation of convection in the COAMPS forecasts and observations. ONR Dynamo meeting, Boston, Aug25-26, 2011

Toshiaki Shinoda, Tommy Jensen, Sue Chen, Maria Flatau(2011) Surface wind and upper ocean variability associated with the MJO simulated by COAMPS. ONR Dynamo meeting, Boston, Aug25-26, 2011.

Tommy Jensen, Toshiaki Shinoda, Maria Flatau and Sue Chen (2011): Coupled modeling of mesoscale air-sea interaction in the Indian Ocean MJO. Presentation at the University of Hawaii, Manoa, Aug.20011